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THE NILE WATERS:

CONTROL AND DISTRIBUTION

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JOINT INTELLIGENCE BUREAU
MINISTRY OF DEFENCE
LONDON

MARCH 1958

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THE NILE WATERS: CONTROL AND DISTRIBUTION

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THE NILE WATERS: CONTROL AND DISTRIBUTION

The equitable distribution of the waters of the Nile is a frequent point of discussion. The river is one of the best documented in the world and the paper at Annex recapitulates some of the basic factors relevant to this question. At Appendix A is a note on generation of hydro-electric power in the Nile basin and Appendix B provides a summary of the principal existing and proposed control installations. Three diagrams and a map are supplied in illustration.

SUMMARY

2. The Nile is 4,150 miles long and its drainage basin includes parts of Kenya, Uganda, Tanganyika, the Belgian Congo, Ethiopia, the Sudan and Egypt. For over 1,600 miles of its course through the Sudan and Egypt it receives no tributaries and it is carefully controlled for irrigation purposes.

3. Of an average 84 milliard cubic metres of water available annually, two-sevenths is supplied by the White Nile which has very different characteristics from that of the Blue Nile and the Atbara which supply four-sevenths and one-seventh respectively.

4. The White Nile, thanks to the lakes and swamps along its course and that of its tributaries, has a relatively even flow throughout the year, but against this, the total loss of water due to these swamps is estimated to amount to about 36 milliards annually. The Blue Nile and Atbara, which are fed by heavy rains on the Ethiopian highlands, have great seasonal fluctuations with a marked high-water period from July to November.

5. Thus, although roughly 84% of the total supplies to the main Nile originate in Ethiopia, at low river, 83% of the main Nile flow is contributed by the White Nile.

6. As well as having a marked seasonal régime, the amount of water flowing in the main Nile varies considerably from year to year. Although the average is 84 milliards, the recorded range is from 42–151 milliards.

7. Further factors affecting schemes to control the waters of the Nile are the very high evaporation rates in Egypt and northern Sudan, and the high silt load carried by the Blue Nile and Atbara, and hence by the main Nile in the flood season.

8. Egyptian cultivation depends wholly upon the ordered regulation of Nile waters, while that of the Sudan is becoming increasingly so. Following upon developments since 1861 and the construction of a complex of 6 barrages, 3 dams and associated canals in the two countries, Egypt now has a cultivated area of 6,150,000 feddans* and the Sudan has a total area irrigated from the Nile of 2,245,000 feddans.

9. The sharing of Nile waters derives from the Nile Waters Agreement of 1929; Egypt is guaranteed the water needed for irrigation as the amount that can be taken by the Sudan outside the flood period is restricted and the construction of all works on the river which might affect the amount of water which reaches Egypt, or its timing, must be agreed by that country. At present of the available average, about 48 milliards is used by Egypt, 4 by the Sudan, 2 are lost by evaporation in Egypt and 30 flow to the sea.

10. Both Egypt and the Sudan are anxious to extend their cultivated area, but even if all Nile water could be used, it would be inadequate to supply all the land in the Nile basin that could be irrigated. The present need is to even out the natural fluctuations of supply and as far as possible increase the amount available annually.

11. All the existing structures have been designed to even out the flow during the course of the year and do not store water from one year to another. In years

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* 1 Feddan = 1·038 acres.

of low total discharge, it is not possible to fill them. Future plans must therefore aim at the construction of long-term storage reservoirs, and the saving of as much as possible of the water lost by evaporation.

12. In 1946 Egypt published a comprehensive plan which included projects to tap two sources previously wasted, namely, the silt-laden high flood of the Blue Nile and the water lost in the Bahr el Jebel swamps of the South Sudan. Long-term storage was planned in Lake Victoria and Lake Albert. Provided certain modifications were included, the Sudan have no basic disagreement with the Lake Tana / Equatorial Nile Scheme, but the only part of the scheme so far completed is the dam at Owen Falls; built primarily for power generation for the benefit of British East Africa, it will, in the future, permit Lake Victoria to be used for over-year storage. Since 1953, however, Egypt's hopes have been focused upon the Aswan High Dam, which would give a storage capacity of 130 milliards; 70 milliards of this would be live storage but an estimated 10 milliards would be lost annually by evaporation.

13. The Sudanese do not favour the High Dam scheme and also wish to reach a new agreement on the question of fair shares of the 30 milliards at present wasted. Any discussions to date on this subject have broken down.

14. Construction of the High Dam project in its entirety by Egypt is dependent upon external and financial assistance, as it is far beyond her internal resources of money, industrial capacity and technical knowledge. Since the withdrawal of the United States and United Kingdom offer of financial assistance in July 1956 there has been no practical progress towards its construction, although some interest has been shown by German and Japanese industrialists. In July 1957 it was announced that the first phase of the project would include the building of the upstream coffer dam and detailed specifications for this are to be completed during the second half of 1958. Even if the High Dam project is carried out, it is not an alternative to the Equatorial Nile scheme and comprehensive control of all the sources will be necessary to enable the fullest use to be made of Nile water for the benefit of inhabitants of the basin.

15. Although the main use of Nile water is for irrigation, there is also a considerable hydro-electric power potential. The primary requirements of irrigation and power are frequently conflicting so that agreement between the riparian States is essential not only upon fair shares of the total supplies available, but also upon a compromise regarding its uses for irrigation, navigation and power generation.

Technical Terms and Abbreviations

The metric system of weights and measures has been used in all cases where volume or vertical river measurements are concerned. In the case of cultivated area, the feddan unit has been employed which approximates to the acre (1 feddan = 1·038 acres).

m.c.m.: million cubic metres.

Mds.: Milliards (one milliard = 1,000 million cubic metres of water per year).

m/d: Millions of cubic metres of water per day.

Cumecs: Cubic metres per second. (11·6 cubic metres per second = 1 million cubic metres per day.) 1 cubic metre of water weighs approximately 1 ton.

Timely Season (period): The time of year when water is required for irrigation in Egypt. The period will be:—

At Mutir	...	December 5–June 14
Mongalla	...	December 11–June 20
Malakal	...	December 21–June 30
Aswan	...	February 1–July 31

Untimely Season (period): The remainder of the year.

ANNEX

THE NILE WATERS: CONTROL AND DISTRIBUTION

Introduction

The Nile is 4,150 miles long; under 1,000 miles of this total flows through Egypt, most of the rest lying in the Sudan and Uganda. Its drainage basin also includes parts of Kenya, Tanganyika, the Belgian Congo and Ethiopia. North of the confluence with the Atbara, 1,676 miles from the sea, the Nile receives no tributaries of significance and from the Sudan / Egypt frontier the river is carefully regulated for irrigation purposes.

HYDROLOGY

Sources of Water

2. At the point of maximum discharge (Atbara) the river has a mean annual discharge of about 87 milliard cubic metres, the principal sources of this water being:—

(*a*) the White Nile (also known in different reaches, as the Victoria Nile, Albert Nile and Bahr el Jebel) which produces two-sevenths of the total flow;

(*b*) the Blue Nile, producing four-sevenths;

(*c*) the Atbara, producing one-seventh.

3. The White Nile, where it emerges from Lake Victoria, has a mean annual discharge of 21 milliards. The lake covers an area of 67,000 sq. km. (25,900 sq. miles) and it is fed by rainfall (which about balances evaporation) and by run-off from the catchment area which includes territory lying in Kenya, Uganda, Tanganyika and the Belgian Congo. The river then flows through swampy Lake Kioga, the time taken for water to pass being long and highly variable, but there is normally an interval of 4–5 months between peak levels on Lake Victoria and Lake Albert. After passing through Lake Albert, the river has gained a further 2 milliards of water originating in Uganda and the Belgian Congo, while between Lake Albert and Mongalla a number of seasonal torrents bring a further contribution of about 4½ milliards, giving a total at Mongalla of 27 milliards. At Bor, the Bahr el Jebel enters the Sudd—a vast swamp, which borders the river for 385 miles to Lake No. Owing to the losses by spill and evaporation, the amount emerging from the Sudd in an average year is only 14·2 milliards, and the average time of travel is about 3–3½ months. The contribution of the Bahr el Ghazal and its tributaries which drain a wide area is only negligible (0·6 milliards) owing also to swamps. The losses incurred in the Sudd area by the Bahr el Jebel are made up by the water contributed by the Sobat (13·9 milliards), originating largely in Ethiopia, and the White Nile discharge at Malakal is thus the same as at Mongalla (27 milliards). Total swamp losses however on the Bahr el Jebel, Bahr el Ghazal and the Baro-Pibor tributaries of the Sobat, amount to an annual average of about 36 milliards (Bahr el Jebel 14, Bahr el Ghazal 19, Baro-Pibor 3 milliards).

4. At Khartoum, the White Nile (25 milliards) is joined by the Blue Nile which makes an average contribution of 51 milliards. Of this total, only 4 milliards is contributed by Lake Tana, the rest being derived from tributaries. Almost the whole supply, however, comes from Ethiopia, as does that of the Atbara, the only other important source of Nile water (12 milliards). Thus of the total supplies to the Main Nile, roughly 84% originates in Ethiopia, and a little less than 16% in Tanganyika, Uganda, Kenya and the Belgian Congo. The contribution from the Sudan is very small and that from Egypt nil.

Regime

5. As well as total average annual availability of water, there are four other important factors in the utilisation of Nile water; these are:—

(*a*) Seasonal availability.

(*b*) Variations in total discharge from year to year.

(*c*) Losses by evaporation.

(*d*) Silt load.

6. The rivers rising in the Ethiopian Highlands (the Blue Nile, Atbara and Sobat) have great seasonal variations in flow. High water lasts from July to November, peak being reached in August and September. The normal mean discharge measured over the period 1912–42 for August is 503 m/d and 172 m/d in the case of the Blue Nile and Atbara respectively, as compared with 11 m/d and nil for April. The Atbara is dry from January to May.

7. The White Nile, thanks to the lakes and swamps of its upper reaches, has a relatively even annual flow. The swamps are a particularly levelling influence, since the loss increases sharply as the discharge at the head of the swamp increases. A discharge of 40 m/d at Mongalla produces a little more than 30 m/d at the tail of the swamp, 160 m/d produces only about 58. Such seasonal change in discharge as is shown by the White Nile in its lower reaches is due to the Sobat flood (see Fig. 1). This river normally starts to rise at the end of April, fed by the Baro and other streams from rains on the western Ethiopian mountains. The seasonal differences are, however, less marked than on the Blue Nile and Atbara, owing to marshes on the Pibor tributary and along the lower course of the main stream. At the height of the Blue Nile flood, the White Nile is ponded back above the junction at Khartoum.

8. The effect on the main Nile of these contrasting régimes is shown by Fig. 1 and by the following table:—

Contribution to Main Nile Flow

	High Flood	*Low River*
	%	%
From the Blue Nile	68	17
From the White Nile	10	83
From the River Atbara	22	—

9. Within Egypt, the Nile year may be divided into three periods:—

(*a*) flood, from the end of July to mid-October;

(*b*) falling Nile, from mid-October to December;

(*c*) low water, from the end of December until the river begins to rise again in July.

10. The above dates are approximately those for Wadi Halfa, near the Sudan–Egyptian border, which may be taken as representing what would take place in Egypt if there were no dams, barrages or irrigation to interfere with the natural flow of the river; a flood peak in September takes about 5–6 days to travel from Aswan to Cairo, and as the river falls the time of travel lengthens to about 13 days.

11. There is a very great *annual* variation in discharge. The recorded range is from 42 milliards (1913–14) to 151 milliards (1878–79); 90 milliards can be considered a good year, 70 milliards a " standard " year, that is, one so low that it is safe to assume that this volume will be reached on the great majority of floods. The problem of Nile control is first to even out the natural fluctuations of supply to agree with demand, and then to increase the standard year.

12. Losses by evaporation are high throughout the Nile basin, but particularly so in the arid regions of central and northern Sudan and in Egypt.

13. About 100 million tons of silt pass down the main Nile in a high flood. Reflecting their contrasting régimes, there is a considerable difference in the silt loads contributed by the Blue and White Nile. The former, with the Atbara, carries large quantities of silt in the flood season, while the latter carries relatively little.

NILE CONTROL

EXISTING CONTROL SYSTEMS

14. Egypt, with an estimated population in 1955 of 23,240,000, depends wholly on the ordered regulation and even distribution of the waters of the Nile. From Atbara, to within a few miles of the Mediterranean, rainfall is insufficient to produce crops. Primitive irrigation has been practised from early historical times and a complex system of dams, barrages, canals and drainage channels has been developed over the last century, and the area under cultivation in 1955 was about 6,150,000 feddans (1 feddan = 1·038 acres).

15. The Sudan has a present population of about 12 million, and the rate of increase has been fast in recent years. There is therefore a need for a greatly increased development of agriculture. In the northern third, agriculture is only possible with irrigation, and in the central zone the rains are so unreliable that supplementary irrigation is necessary to mature most types of crops. Much the most important source of supply is the Nile, and the total area at present irrigated from this source is about 2,245,000 feddans.

16. In 1861 the first barrages were completed at the head of the Delta, but, owing to engineering difficulties, they were not brought into use until 1889. Their purpose is to raise river levels sufficiently (*i.e.*, by about 6½–14 ft.) to enable water to be diverted into the main canals which take off above them. There are now six barrage systems in Egypt fulfilling this function and enabling perennial irrigation to be carried on (see Fig. 2). The original Delta barrage, although the structures are still in place, has been replaced by the Muhammed Ali Barrage, built just downstream and brought into use in 1940.

17. From the end of the 19th century, the natural low-water flow (February–July) was insufficient, and the problem became one of storing " untimely " water from the period of surplus, for release as " timely " water in the period of shortage. (Any water flowing at any point in the Nile system at such a time as to reach Aswan between 1st February and 31st July is " timely.") Owing to the silt carried by the Atbara and the Blue Nile and the consequent danger of reservoir deposition, the " untimely " period can be divided into two, according to whether the water can be safely stored or not. The water in these rivers and in the main Nile in August and September (Aswan dates) has hitherto been considered unsafe for storage. Thus, in an average year, one-fifth of the total flow is " timely," one-fifth " untimely "—but not storable, and three-fifths is " untimely " but is storable.

18. The Aswan Dam was the first of the storage dams to be constructed (1902). This reservoir stores water from the tail of the flood in October and is first drawn on in February. The solid granite masonry dam is 1¼ miles long and, twice heightened, now stands at 130 ft. This provides a storage capacity of 5·3 milliards, and backs up water to the foot of the Second Cataract above Wadi Halfa.

19. The Sudan was less developed agriculturally than Egypt, and it was not until 1925, with the inception of the Gezira Cotton Scheme, that the Sennar Dam was built on the Blue Nile. This structure fulfils the double purpose of a barrage and a dam, and has a present storage capacity of 929 m.c.m. The reservoir is partly filled in July and again in October and November; the water is used (i) for irrigation at Gezira between 1st February and the end of March and (ii) is released to Egypt in April as an addition to the whole of the *natural* low-stage flow, which is not interrupted.

20. In 1937, as Egypt's needs became greater, the Gebel Aulia Dam (reservoir capacity about 3·5 milliards) was built in the Sudan. The reservoir is filled gradually every year between early July and early October with the relatively silt-free water of the White Nile. The water is ponded back (the effect being felt for 370 miles upstream) while the Blue Nile is in flood, thus increasing a natural tendency, and is released in the period early February–May according to Egyptian requirements. Losses by evaporation are high and the capacity is equivalent to about 2·5 milliards at Aswan.

21. From February to July, except in very high years, no water reaches the sea until it has first been used on the land; the Rosetta branch of the Nile below the Delta barrage receives no water from upstream at this time, and the Damietta branch very little. A temporary earth bank (Sudd) is constructed annually near the mouth of the Damietta to prevent the inflow of salt water, and plans exist for its replacement by a permanent structure at Fariskur. The Rosetta branch is sealed by a permanent barrage at Idfina.

INTERNATIONAL AGREEMENTS

22. The sharing of Nile Waters derives from the Nile Waters Agreement of 1929 between Great Britain and Egypt, which accepted the report of the

International Nile Waters Commission of 1925. This agreement mainly concerned the Sudan but also covered other countries under British Administration. The agreement, with its attached working arrangements, by restricting the amount of water that could be taken by the Sudan outside the flood period, guarantees to Egypt the water needed for existing agriculture. The Sudan might not, without prior consent by Egypt, take any action which would affect the arrival of Nile water in Egypt. Egypt might not, without first agreeing measures to safeguard Sudanese interests, undertake construction works.

23. The Sudan, since it became independent, has not recognised the Nile Waters Agreement as such, but, on the other hand, the existing structures at Sennar and Gebel Aulia continue to be regulated according to its terms. In 1952, in an exchange of notes, Egypt and the Sudan agreed *inter alia* that the respective shares of the two countries, in water made available from any future control projects within their territories, should be decided in discussions between the two countries before any new work is undertaken.

24. In Ethiopia the Anglo-Egyptian agreement of 1902 provides that works shall not be constructed in that country without Sudanese consent. Basic surveys of the Blue Nile basin in Ethiopia were begun in 1957 by American experts under agreement between the Ethiopian Government and the International Co-operation Administration. The initial phase of the project is expected to take at least 18 months and is an essential preliminary to any appraisal of Ethiopian water resources.

25. The Nile, apart from its Blue Nile tributaries, is one of the best documented rivers in the world, and since 1902 elaborate flow records have been maintained and measurements taken by the various irrigation and hydrological departments concerned in Uganda, the Sudan and Egypt. Such records are of particular importance to Egypt, since all the arrangements for the annual programme of irrigation depend upon forecasts of the timing and height of natural flood and of total availability of water. The Egyptian Irrigation Department maintains offices at Khartoum, Gordon's Tree (Dockyard), Gebel Aulia (Dam) and Malakal in the Sudan, and at Jinja in Uganda.

FUTURE DEVELOPMENTS

26. At present, of the average 84 milliards of Nile water available annually (as measured at Aswan), about 48 milliards is used by Egypt, 4 by the Sudan, 2 are lost by evaporation in Egypt and the remaining 30 milliards flow to the sea and are wasted during the "untimely" period. In both Egypt and the Sudan, availability of Nile water is the controlling factor in the expansion of the cultivated area. The area under cultivation in Egypt is about 6,150,000 feddans and the area capable of being cultivated, given adequate irrigation, is usually quoted as 7·1 or 7·5 million feddans, but estimates as high as 8, 10 and even 15 million feddans have been made. 7·1 million feddans would require 58 milliards of water, but to meet the requirements of 10 million feddans, virtually all the water in the Nile in an average year would be needed.

27. In the Sudan, present consumption of Nile water is 4·1 milliards for the irrigation of 2,245,000 feddans. Projects exist for an increase in this area by 4,375,000 feddans, and a forecast of ultimate Sudanese water requirements of 25 milliards (as at Aswan) has been made.

28. Thus, even if all Nile water could be used, it would be inadequate to supply all the land in the Nile basin, on which crops could be grown by irrigation. No schemes at present exist for large-scale irrigation in the Lake Plateau area of Uganda, Kenya, Tanganyika and the Belgian Congo. Rainfall is adequate for crops, but the average annual fall is only about 50 inches, which is not high for a tropical area. A requirement for Nile water for partial irrigation is therefore likely to develop. In 1955 the British Government submitted a note to the Egyptian and Sudanese Governments in which the right was reserved to negotiate an agreed share of water on behalf of the British East African territories, at an appropriate time. In this area, however, the use of water for generating electric power is at present, and will remain, of far greater interest than its use for irrigation purposes.

29. The main reason for control of Nile waters is for irrigation, but in addition its uses for domestic water supplies, generation of hydro-electric power and navigation have to be balanced, as well as such factors as flood control, availability of natural flood plain grazing and fisheries. The optimum conditions in respect of each of these is frequently incompatible, necessitating international and internal compromise. The nearest approach to complete use of Nile water can only be accomplished by levelling out the great seasonal and annual variations by storage, and by saving as much as possible of the water at present lost by evaporation. Also required is agreement between the riparian states concerned on fair shares of the water for their frequently conflicting requirements and in particular for irrigation, navigation and power generation.

30. All the installations mentioned in paragraphs 16 to 21 above, provide only for seasonal storage and in years of very low discharge it may not be possible to fill the reservoirs. The remedy is long-term, sometimes known as century* or "over year" storage, by which the surplus of good years can be used as a reserve for years of drought and by which the dangers of serious floods can be minimised. In connection with this, the main schemes put forward by Egypt and the Sudan since 1945 are the Lake Tana/Equatorial Nile Scheme, the Roseires Dam and the Aswan High Dam. Other potential projects are included in Appendix B.

THE LAKE TANA/EQUATORIAL NILE SCHEME

31. This is a comprehensive plan drawn up by Egypt and published in 1946,† with the intention of tapping two sources of water previously wasted, namely the silt-laden high flood of the Blue Nile, and the water lost in the swamps by the Bahr el Jebel. In the case of the latter, after detailed survey for the Sudan Government by the Jonglei Investigation Team, 1949–53, certain modifications were suggested, but in both cases a number of separate (but for optimum results, interdependent) projects were involved.

32. *On the Blue Nile.*—A storage dam is projected at Lake Tana in Ethiopia for irrigation, flood protection and supplementary reserve, for both Egypt and the Sudan. Power generation for the benefit of Ethiopia would also be possible. An agreement between Egypt and the Sudan was reached on this project in 1935 and 1946, but no settlement has yet been reached with Ethiopia. In February 1958 it was reported that the Ethiopian Government was considering calling a conference to discuss this and other matters.

33. *On the Equatorial Nile* (*Bahr el Jebel and White Nile*).—A number of projects are envisaged which form part of an integrated whole (none can be used effectively without the others). They include:—

(i) a dam at Owen Falls to provide storage capacity in Lake Victoria (completed—see paragraph 36);

(ii) a dam near Masindi Port to convert Lake Kioga into a balancing reservoir;

(iii) a dam at either Nimule or Mutir to provide storage capacity in Lake Albert;

(iv) one or more dams between Nimule and Rejaf to provide balancing reservoirs for counteracting the effects of the inflowing seasonal torrents;

(v) a 185-mile canal or canals, with a regulator across the river to bypass the Sudd region from Jonglei to the mouth of the Sobat, which would prevent over spilling and abnormal loss from evaporation.

34. *On the Main Nile.*—One or more reservoirs to be built between Atbara and Wadi Halfa for flood protection and annual storage. Sites were surveyed and that at Merowe favoured, but since 1953 all attention has been turned to the High Aswan Dam Project (see paragraph 42 below).

35. The Sudan, provided that vital interests can be safeguarded, has no fundamental objections to the Equatorial Nile scheme. Some concern is felt, however, that the Jonglei Canal scheme will affect the 660,000 pastoralists living in the area who are dependent upon the natural fluctuations of the Nile for their livelihood. Control would result in a reversal of seasonal flow at Mongalla and in

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* The capacity necessary to provide water in 99 years out of 100.

† "The Future Conservancy of the Nile." The Nile Basin, Vol. VII by H. E. Hurst, R. P. Black and Y. M. Simaika.

loss of grazing land; radical changes in the local economy would be necessary, and the Sudan furthermore considers that any water saved would naturally become the property of the Sudan Government, it now being lost from Sudanese soil. Under the original plan, estimated saving would be 6·9 milliards in the " timely " and 0·9 milliards in the " untimely " season.

The Owen Falls Dam

36. Of the above projects, only the Owen Falls Dam, 1¾ miles from the outlet of Lake Victoria, has so far been built. The main object of this dam, completed in 1954, is the generation of power (present capacity about 90,000 kW., ultimate capacity 150,000 kW.—see Appendix A, paragraph 3) but it can be operated to enable Lake Victoria to be used for over-year storage; a range of 3 metres (9·8 ft.) in the level of the lake will give a storage capacity of 201 milliards.

37. Construction of the dam was the subject of British-Egyptian discussions under the terms of the 1929 Nile Waters Agreement. Following upon these discussions, Egypt has paid the cost of raising the dam to the level required for storage (1 metre at £226,500) and £980,000 to the Uganda Electricity Board in recognition of unspecified damage to interests below the dam. They also undertook to bear the cost of compensation for any adverse effects or disturbance of lakeside interests. This compensation would be assessed by a special survey to be undertaken by a British firm of consultant engineers appointed by Egypt (provisionally Sir Alexander Gibb and Partners).

38. The height of the river above the dam was brought to lake level during 1956. The future permitted maximum of the lake will be 1·3 metres above the recorded highest figure, but storage will only begin five years after the payment of compensation and the survey to assess this has not yet been made. Many years will in any case be necessary to bring the lake to its new mean level of 11·30 metres on Entebbe gauge. The mean for 1955 was 10·34, and the stoppage of the entire normal annual discharge would only raise the lake by 28 cms.

39. Before storage begins, the " initial " or " temporary " discharge from the lake is to be on " the run of the river," the future object being to equalise the outflow to 20·08 milliards per year (55 m/d), the long-term mean at the lake exit. When the Lake Albert Dam is constructed, however, outflow will be varied during the year according to storage requirements in that lake. The range of discharge rates agreed was between 44 m/d (505 cumecs) and 100 m/d (the previous natural maximum). The highest possible minimum or constant discharge is, however, in the interests of Uganda for power generation, and any further negotiations before storage is ultimately started might result in a new agreement.

40. Only when the other schemes in the Equatorial project are completed, particularly the Jonglei canal, will the Owen Falls Dam represent an important factor in the Egyptian irrigation system.

The Roseires Dam

41. This is a Sudanese project for a comparatively small reservoir (capacity about 3 milliards) on the Blue Nile, which will provide for a further 1,200,000 feddans of Gezira irrigation. The dam has been designed by Sir Alexander Gibb and Partners in association with M. Andre Coyne of Paris. Construction has not yet started.

The High Aswan Dam (Sudd al Ali) Project

42. This is an ambitious plan for the construction of a dam at a point about 4 miles upstream of the existing Aswan dam, which has evolved out of a suggested third heightening of the latter.

43. The retaining dam, according to preliminary plans, would have a length of 3·1 miles and a height of 361 ft. above the river bed. The reservoir formed would have a length of nearly 400 miles which would flood over 90 miles of Sudanese territory and submerge the town of Wadi Halfa. Blue Nile water would be stored at high flood. Planned total capacity is about 130 milliards.

44. Evaporation and silting have both been the subject of controversy. Evaporation loss has been estimated at about 10 milliards per annum, but it has been pointed out* that of the projects so far investigated for the purpose of storing waste Blue Nile and Atbara flood water, there is none with the capacity which is available at the Sudd al Ali site or which is superior to it in the matter of evaporation losses; these are equally inevitable anywhere in the northern half of the Sudan. Thirty milliards of dead storage for silt deposition is planned and it is estimated that several hundred years would elapse before the reservoir would lose a quarter of its capacity. There is also risk of lateral seepage from the reservoir through porous rock strata.

45. A further 30 milliards of the total capacity would give the necessary margin for flood control. This is a necessary measure since the Nile in high flood flows considerably above the level of the surrounding countryside.†

46. The High Dam would be of great and immediate importance to Egypt, where the general standard of nutrition is low and where food production is failing to keep pace with the rapid rise in population. It would enable Egyptian irrigation ultimately to be increased by 30 per cent. and would convert some 700,000 feddans of intermittently irrigated land to perennial irrigation, as well as irrigating an additional 1·3 million feddans for the first time. It would obviate the necessity for other reservoirs on the main Nile (paragraph 34 above) and for the Wadi Raiyan flood control project. A power station of 750,000 kW. capacity is also planned as part of the High Dam Scheme. The total cost is estimated at 1,300 million dollars and it would take 12–16 years to complete.

47. The Sudanese do not favour the High Dam project and no agreement has been reached between the two countries on the subject. They feel that since it is remote from areas of use, they have little to gain from it; against this can be argued that, if a fair agreement on the uses of water at present going to waste could be reached, the storage of water at Aswan would permit the release to the Sudan of water from the Blue Nile at low stage; at present this is entirely used by Egypt. Construction of the High Dam, however, would inevitably postpone completion of other major schemes in which the Sudan has a greater interest. The question of fair shares of water is a crucial point. The Sudan believes that any discussion on Nile waters should be based upon the total figure of 30 odd milliards running to waste, and not on that remaining for disposal and allowing for evaporation after the construction of the Aswan dam. Less developed agriculturally, they also wish the amount of land available for future irrigation to be taken into account, rather than that an assessment should be concerned solely with present population and needs.

48. The Sudanese Government's technical advisors have been working on a revised overall plan for Nile control; this work has included the reappraisal with the aid of electronic computors of all available statistical material. Egypt-Sudan discussions on the High Dam Scheme were renewed in January this year, but proved inconclusive.

49. Apart from the advantages to Egypt of the High Dam mentioned above, there is the added attraction that it lies within Egyptian territory. Disadvantages which have presumably been weighed up include that of vulnerability. The whole of Egypt's control of the Nile, both in flood and for irrigation, as well as much of the country's hydro-electric power, would be concentrated in one spot. A further disadvantage is the question of cost; a series of dams can be built gradually in accordance with the requirements of the economic situation, whereas construction of the High Dam would be dependent upon external financial and industrial assistance, as it is on a scale far beyond Egypt's internal resources of money, industrial capacity and technical knowledge.

50. Following the withdrawal of the United States and United Kingdom offer of financial assistance in July 1956, and despite some German and Japanese interest, there has been no practical progress towards construction of the dam. In July 1957 a revised scheme was announced; this would consist of a first phase in the construction of the full scheme, including the building of the upstream coffer dam (150 ft. high) which would act as an independent dam for the time being, allowing a longer than normal delay before the erection of the main structure. A much

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* By H. E. Hurst, Letter to the *Times*, June 4th, 1957.

† In upper Egypt, the difference in level may be about 3 ft., in middle Egypt 3–5 ft. and below Cairo it is 9–13 ft. and in places as much as 16 ft.

smaller storage capacity would result (8 milliards as against 70 milliards "live" storage for the High Dam) but the cost of £E.60 millions over five years would be met from Suez Canal dues. Preliminary studies have been made for this coffer dam and detailed specifications are planned to be completed during the second half of this year.

51. Substitution of a project to utilise the Wadi Raiyan depression, south of Faiyum, for storage is also said to be under discussion. This scheme has been mooted for many years as a means of flood protection and storage. The reservoir then envisaged, however, had a storage capacity of about 4 milliards, so, unless radically altered, this would not be a true substitute for the many times greater storage capacity of the projected Aswan High Dam reservoir.

52. Even if Egypt is successful in carrying out the Sudd al Ali project in its entirety, this dam and the Equatorial Nile schemes are not alternatives, and comprehensive control of all the sources will be necessary to enable the fullest use to be made of Nile waters, for the benefit of inhabitants of the basin.

Appendix A

GENERATION OF POWER IN THE NILE BASIN

The main importance of the River Nile lies in the provision of water for irrigation; nevertheless a considerable hydro-electric power potential exists. Agreement between the riparian states concerned is essential, as in any question of water conservancy there is frequently a conflict of interests between requirements for storage, discharge rates and timing of releases for irrigation, as against optimum flow for power generation.

2. The principal existing, planned or potential power schemes and sites are as follows:—

Owen Falls Dam (Uganda)

3. Ultimate capacity, 150,000 kW., to be provided by 10 turbo-alternator sets of 15,000 kW. The fifth and sixth sets were almost ready for service at the end of 1956; No. 7 set was being erected and draught tubes and cones of turbines 8, 9 and 10 had been installed. As adequate generating capacity is available to fulfil present demand, the main efforts of the Uganda Electricity Board have been concentrated upon distribution. A power line to Kenya has been constructed and off-take commenced in January this year.

4. Although the dam is at present in excess of requirements, it has been estimated that total capacity will have been reached by 1965 or thereabouts. The question of the construction of a second dam is therefore under active consideration.

Other Sites Between Lake Victoria and Lake Albert

5. Surveys of the Victoria Nile between Lake Victoria and Lake Kioga and between Lake Kioga and Lake Albert have been made for the Uganda Electricity Board by Kennedy and Donkin (East Africa) and Sir Alexander Gibb and Partners. There is a fall of 330 ft. (of which 67 ft. is developed by the Owen Falls Dam) between Ripon Falls and Namasagli and 1,370 ft. between Lake Kioga and Lake Albert. Reports indicate a potential of at least 500,000 kW. in the case of the first stretch and between 1,100,000 kW. and 1,500,000 kW. in the case of the second. Trial bores at a proposed station site some miles below the Owen Falls Dam have been made.

Lake Tana (Ethiopia)

6. Various proposals have been made for water storage in this lake, including the construction of a 6-mile tunnel from the south-west corner of the lake to the River Balas. A head of about 300 metres (980 ft.) could be made available for the generation of power.

7. There are undoubtedly many possible dam sites on the Ethiopian Blue Nile and its tributaries, but initial survey and mapping of the area is only now in progress.

Sabaloka Gorge (Sudan)

8. Potential site for dam at downstream end of 12-miles long gorge. It is not the best site on the Sudanese main Nile but it is the nearest to Khartoum.

Fifth Cataract (Sudan)

9. Potential site, not yet surveyed in detail, but a head of 20 metres (66 ft.) can probably be developed.

Fourth Cataract—Merowe (Sudan)

10. Potential site for reservoir with a capacity of 10 milliards. The site could be developed for hydro-electric power with a head of 50 metres (164 ft.). A combination of storage reservoir and power dam would be possible by the sacrifice of some irrigation and power potential.

Semna Gorge (Sudan)

11. Potential site for a reservoir with a capacity of 25 milliards. It could also be used for power, or a combination of both power and irrigation.

The Nile in Egypt

12. All the existing barrages in Egypt were initially designed solely for irrigation purposes. For generation of power they all suffer from the disadvantage of lack of a constant head of water. There is a small hydro-electric power plant at Nag Hammadi and it is reported that Egypt will invite tenders for the conversion of the barrages at Isna, Asyut and Zifta. The main planned and potential power output is connected with the existing Aswan dam and with the Aswan High Dam.

Aswan Low Dam

13. The existing Aswan irrigation barrage is being modified by the construction of a second dam on the western side of the reservoir. In future, most of the water will be released through this dam and via seven turbines into a system of four tunnels under the old navigation locks back into the river. Work is well advanced and the first turbine equipment was being installed early in 1957. Capacity is to be 344 mW. and the work is due for completion during the period 1959–61. Progress may have been delayed by the withdrawal of the main French contractor. Output will vary greatly and will be reduced to only 25% of capacity in the low-water months (May–June).

Aswan High Dam

14. According to the preliminary plans, four power tunnels on the west bank (4,920 ft. long and 46·6 ft. diameter) would serve four underground power stations, each with four sets of turbines of 72 mW. apiece. The huge reservoir would permit even operation all the year and would also enable the turbines in the "low" Aswan Dam downstream to operate at 90% capacity throughout the year.

APPENDIX B

NILE CONTROL INSTALLATIONS (ACTUAL AND PROPOSED)

NOTE.—The installations are listed from source to mouth:—

A: on the White Nile; B: on the Blue Nile; C: on the Atbara; D: on the Main Nile.

Serial	Installation	Purpose and Remarks
White Nile A.1. Uganda	*Owen Falls Dam* (completed 1954). *Location:* 1¾ miles from the outlet of Lake Victoria. *Dimensions:* Length, 2,725 ft.; height, 85 ft. Six central sluices and power race pass an average of 55 m/d (20 milliards per year), range 44 m/d to 100 m/d. *Reservoircapacity:* 201 milliards in 3-metre range between 9·80–12·80 metres on Entebbe gauge when filled.	(*a*) Power generation. Ultimate capacity 150,000 kW. (see Appendix A, paragraph 3). (*b*) Over year storage in Lake Victoria as an integral part of the Equatorial Nile Scheme. Storage has not yet begun. Until serials A2–6 below, and particularly A.3 and A.6 are built, this installation will not be an important factor in Egyptian irrigation. Partly because of losses in the Sudd and partly because in any increased discharge much would go in raising levels in Lake Kioga and Lake Albert before any increase is passed down stream.
A.2. Uganda	*Lake Kioga Regulator* (proposed). *Location:* Masindi Port or vicinity. Barrage to hold 3–4 metres (9·8–13 ft.) of water.	To pass variations in Owen Falls discharge to Lake Albert without delay. At present any increased discharge is delayed by 2–3 months.
A.3. Uganda	*Lake Albert Dam* (proposed). *Location:* Mutir.	Over year storage in Lake Albert. A considerable volume could be stored without undue inconvenience to Uganda or Belgian Congo. All available records are being analysed to decide a reasonable size. Egyptian suggestion is for a reservoir of 49 milliards, operating between 10·00 and 18·50 metres on Butiaba Gauge. This upper level is not acceptable to the Sudan. Controlled discharge to be 90 m/d in the "timely" season (December 11–June 20) and 9·9 m/d in the "untimely," or as near a mean average annual discharge of 27 milliards as possible. Further negotiations will be necessary between Uganda, Egypt and the Sudan to agree the maximum level acceptable to Uganda which will provide an adequate measure of flood control for the Sudan.
A.4. Uganda	*Nimule Dam or Regulator* (proposed).	To regulate the run-off from the Torrents in high years and control level for navigation. Proposal for siting the Lake Albert Dam at this site is not acceptable to Uganda, owing to resulting loss of cultivated land.
A.5. Uganda	*Bedden Rapids.* Potential site for low dam.	Further control of the Torrents if necessary, possibly associated with power-generation.
A.6. Sudan	*Jonglei Canal and Headworks* (proposed). Jonglei is the proposed site for a regulator and take-off point for a 185-mile by-pass canal or canals leading by direct line to the White Nile near the mouth of the Sobat. Egyptian plan: ultimate capacity 80 m/d, by stages of 10 m/d, 27·5 m/d, 55 m/d. Jonglei investigation team proposals: normal capacity 35 m/d—of which 5 m/d would be carried by an irrigation canal. Flood discharge capacity 65 m/d.	To avoid excessive losses resulting from the flooding of the Bahr el Jebel. At 55 m/d a saving of 6·9 milliards in the "timely," and 0·9 milliards in the "untimely" season is calculated. Net benefit (*i.e.*, less water required locally) 7·11 milliards. Net mean benefit under the revised (Jonglei team) project, 6·8 milliards.

Serial	Installation	Purpose and Remarks
White Nile continued—		
A.7. Sudan	*Gebel Aulia Dam* (completed 1937) *Location:* 28 miles south of Khartoum. 1,490 ft. long masonry dam with flanking abutments giving a total length of 3·1 miles. Entire flow passes through sluices. Backwater effect 370 miles. *Reservoir capacity:* About 3·5 milliards. Filled: Early July–early October. Emptied: Early February–May. Maximum head: 19·8 ft.	Seasonal storage: the reservoir impounds silt-free White Nile water during the Blue Nile flood, for release to Egypt at low river stage. Owing to high evaporation rate only about 2·5 milliards of the total reaches Aswan. In 1952 Egypt agreed to the Sudan drawing 200 million cubic metres during the restricted period by raising the level by 10 cms. (Subject to a criterion for low years.) This is to be regarded as an advance on the Sudan's share of the next Nile project or projects to be constructed.
Blue Nile B.1. Ethiopia	*Lake Tana Dam* (proposed) Various proposals exist for damming the Blue Nile at the lake exit, but storage would be limited because the level could not be drawn far down without heavy excavation. One proposal suggests a 6-mile tunnel at south-west corner of lake to connect with the headwaters of the River Balas. Local topography would give a head of 300 metres (980 ft.) for power generation.	(*a*) Storage in flood season (roughly July–December) for increased irrigation downstream in the Sudan and Egypt during the low season (roughly January–June). (*b*) Generation of power for Ethiopia. As total annual average discharge is only 4 milliards, overall effect on the Blue Nile flood is slight.
	Other sites on the Blue Nile are believed to exist but no detailed survey has yet been made.	
B.2. Sudan	*Roseires Dam* (proposed). *Location:* Proposed dam has been designed by Sir Alexander Gibb and Partners and M. Andre Coyne of Paris. Central sluice dam of heavy buttress type, length about 2,950 ft. with flanking embankments giving a total length of nearly 5 miles. Surface spillway with crestgates. Spillway and sluices capable of carrying a peak discharge of 15,000 cumecs. *Reservoir capacity:* with surface of the full reservoir at 480 metres (1,575 ft.) above sea level, capacity about 3 milliards; backwater effect about 62 miles.	Will serve the Kenana Extension (1,200,000 feddans) of the Gezira irrigated area.
Blue Nile B.3. Sudan	*Sennar Dam* (completed 1925). *Location:* Central masonry section of 1,970 ft. contains 80 low-level sluices. On top of these a 980 ft. spillway is divided into sections which can be closed off by steel panels when the flood has passed. Total length with embankments just over 3 kms. (1·9 miles). Carries road and railway from Sennar to Gedaref. *Reservoir capacity:* Surface level of full reservoir 422 metres (1,385 ft.) above sea level: capacity nearly 1 milliard. Filled: to within 4½ metres (14·7 ft.) of full supply level during the last half of June and early July. Filling completed October–November. Emptied: February 1st–mid-May. Maximum head: 55 ft.	Serves Sudan Gezira irrigation and stores water annually for Egypt. The full low stage water is passed to Egypt; commands Gezira irrigation July–March. Egypt agreed in 1952 to the raising of the water level in the reservoir by 1 metre (subject to a criterion for low years).
Atbara C.1.	*Khashm el Girba* (proposed). Site at downstream end of 3·7 mile gorge. Suggested reservoir level of 473 metres (1,552 ft.) a.s.l. would give a reservoir capacity of a little over 1 milliard. Backwater effect to Setit.	Annual storage. It would irrigate about 500,000 feddans of potentially good agricultural land.
Main Nile D.1. Sudan	*Sabaloka Gorge.* Possible site for a hydro-electric power dam at the downstream end of a 12-mile gorge.	This is not the best Sudanese site on the main Nile, but is nearest to Khartoum.

Serial	Installation	Purpose and Remarks
Main Nile	*continued—*	
D.2. Sudan	*The Fifth Cataract* Possible site for power development, not yet surveyed in detail. Probable head of 20 metres (66 ft.).	
D.3. Sudan	*The Fourth Cataract* (proposed). Near Merowe. Excellent site at Hamdab Is. for a reservoir at 295 metres (968 ft.) a.s.l. giving a capacity of 10 milliards. Power site with head 50 metres (164 ft.).	Annual storage for irrigation in Egypt, or power development, or a compromise of both.
D.4. Sudan	*The Semna Gorge* Good site for reservoir, 220 metres (722 ft.) a.s.l. would give capacity of 25 milliards. Backwater to Kerma.	For irrigation in Egypt and/or power.
D.5. Egypt	*Aswan High Dam* (*Sudd el Ali*) (proposed). Location: 4 miles upstream of D.6. Length: 16,370 ft. (3·1 miles). Height above river bed: 361 ft. Preliminary plan: massive rockfill dam, clay core, upstream blanket and grout cut-off. Upstream coffer dam to be incorporated in upstream blanket. 7 diversion tunnels 6,883 ft. by 54 ft. diameter: 4 power tunnels, 4,920 ft. by 46½ ft. diameter. Reservoir: nearly 400 miles long, capacity about 130 milliards, of which 30 milliards dead storage, 30 milliards for flood control.	Over year storage. Irrigation of 2 million feddans. Power station capacity 750,000 kW. Cost estimated at 1,300 million dollars, time 12–16 years. Very high evaporation loss, estimated at 10 milliards.
D.6. Egypt	*Aswan Dam* (completed 1902, heightened 1912, 1934). Length: 7,050 ft. Height above bed level: 130 ft.; above foundation level 174 ft. Solid granite masonry, founded on granite with 180 sluices and lock. Reservoir capacity: 5·3 milliards. Ponds back 360 kms. (223·7 miles) to foot of second cataract above Wadi Halfa. Filling begins October and is completed by end-January. Is first used in February or March. From July onwards, in flood, all sluices are open. Maximum head is then 6–9·8 ft. January–April inclusive up to 98 ft.	Annual storage. Collects and stores water from the tail of the flood to supplement deficiencies in spring and early summer. Key installation in the present Egyptian irrigation system. Hydro-electric power installation now being constructed (see Appendix A, paragraph 13).
D.7. Egypt	*Isna Barrage* (completed 1909). Overall length: 2,950 ft. Sandstone. 120 openings and lock maintains head of 16·4 ft.	Raises river level during flood so that water can flow into irrigation canals supplying Basin irrigation in the Aswan–Kena area.
D.8. Egypt	*Nag Hammadi Barrage* (completed 1929). Total length: 2,700 ft. Granite masonry and limestone: 100 openings and lock. Maintains head of 14·7 ft.	Controls supply of water to the Fouadiya and Faroukiya canals and provides water for Basin irrigation.
D.9. Egypt	*Asyut Barrage* (completed 1902). Total length: 2,750 ft. Sandstone 110 openings and lock. Maintains head of 14·7 ft.	Supplies whole of west bank perennial irrigation system from Asyut to Cairo through the Ibrahimiya Canal.
D.10. Egypt	*Wadi Raiyan Reservoir* (proposed). Suggested scheme for diverting water into the Wadi Raiyan depression south of the Faiyum. Would involve the cutting of a large canal across Middle Egypt.	For storage and flood control.

Serial	Installation	Purpose and Remarks
Main Nile	*continued—*	
D.11. Egypt	*Delta Barrages* (completed 1889 and 1940). (*a*) *Old Barrages* over (i) Rosetta Branch. Length 1,546 ft. Multi-span masonry arch with 61 openings and locks. (ii) Damietta Branch 1,216 ft. Concrete and granite, 51 sluice vents and lock. These barrages, which were brought into use in 1889, are no longer in use, having been replaced in 1940 by: (*b*) *Muhammed Ali Barrages—* (i) Length, 1,749 ft., masonry with 47 openings and lock; (ii) 1,332 ft., concrete with masonry-facing. 34 sluices and lock. Maximum head about 11·5 ft.	The two barrages supply the whole delta via the Beheira, Menufiya, and Taufiqiya Canals, also the Ismailiya Canal. In flood (15/20 August–end-September) all sluices are open. Fully closed February to August.
D.12. Egypt	*Zifta Barrage* (completed 1902). Over Damietta branch. Length 1,300 ft. Brick and masonry with 50 openings and lock. Maximum allowable head 13·1 ft.	Supplies water for perennial irrigation of north-east part of Delta. Maintains a head of water on the Bahr Shibin Canal.
D.13. Egypt	*Idfina Barrage* (completed 1951). Over Rosetta Branch. Length, 1,606 ft. Mass concrete floor; faced granite blocks. 46 openings and lock.	Supplies water for perennial irrigation in north-west part of Delta and has replaced temporary Sudd preventing inflow of salt water.

DIAGRAM OF THE NILE IRRIGATION

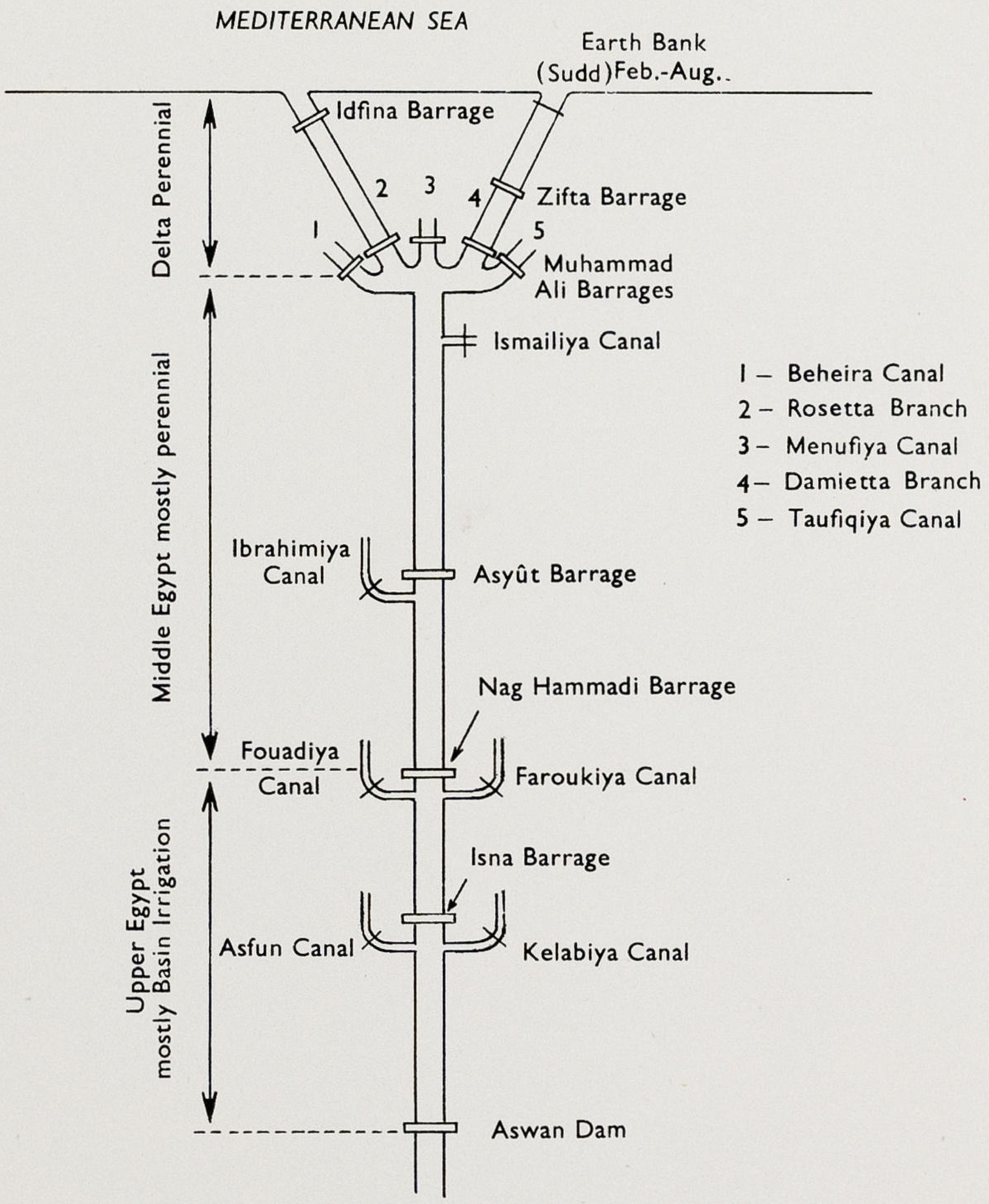

Fig. 2

Compiled and drawn by J.I.B. April '58

DISCHARGES OF THE NILE & ITS MAIN TRIBUTARIES (AVERAGE 1912-1936)

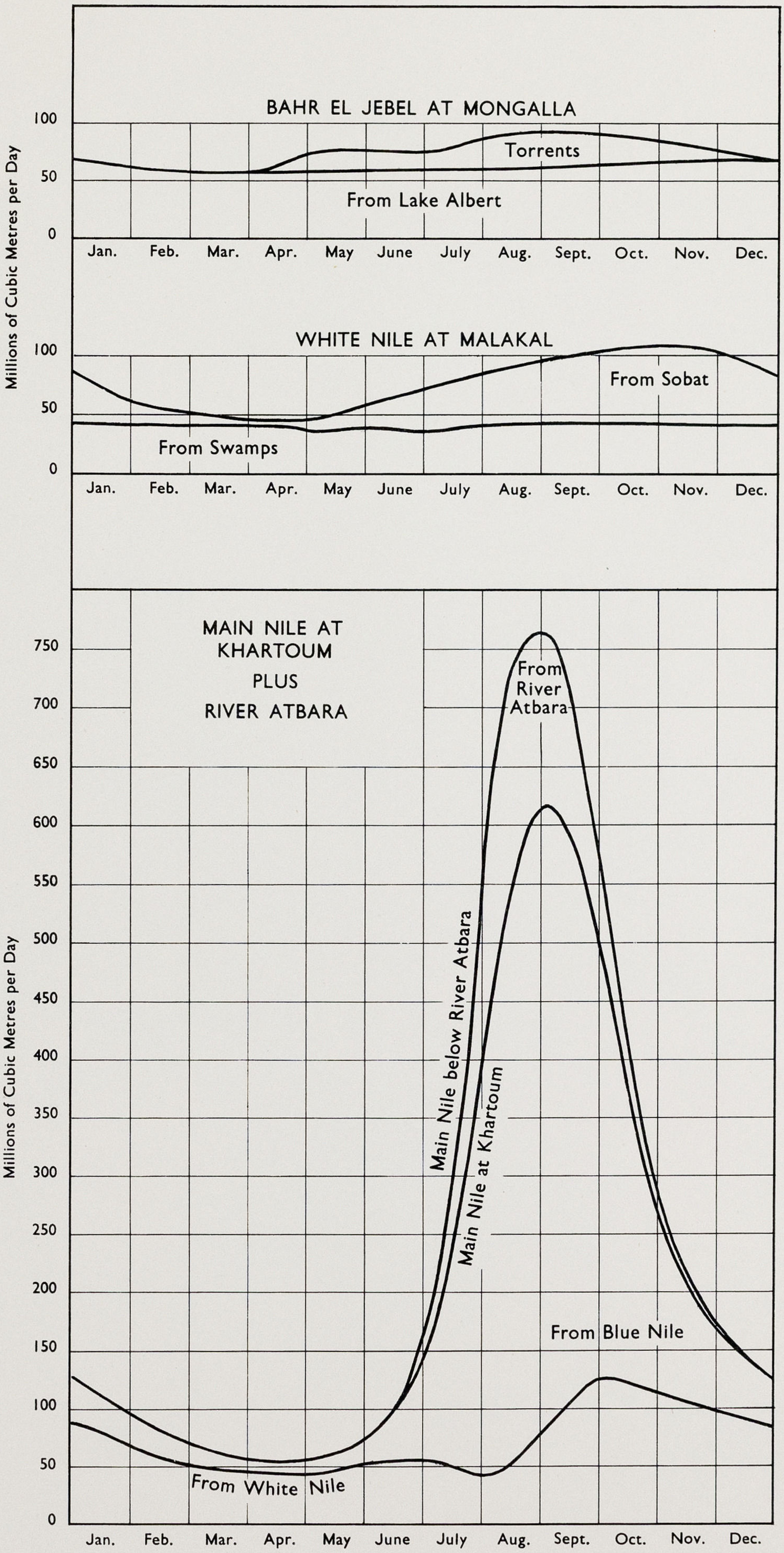

FIG. 1 [From: The Nile Basin (Vol. V) by H. E. Hurst & P. Phillips]

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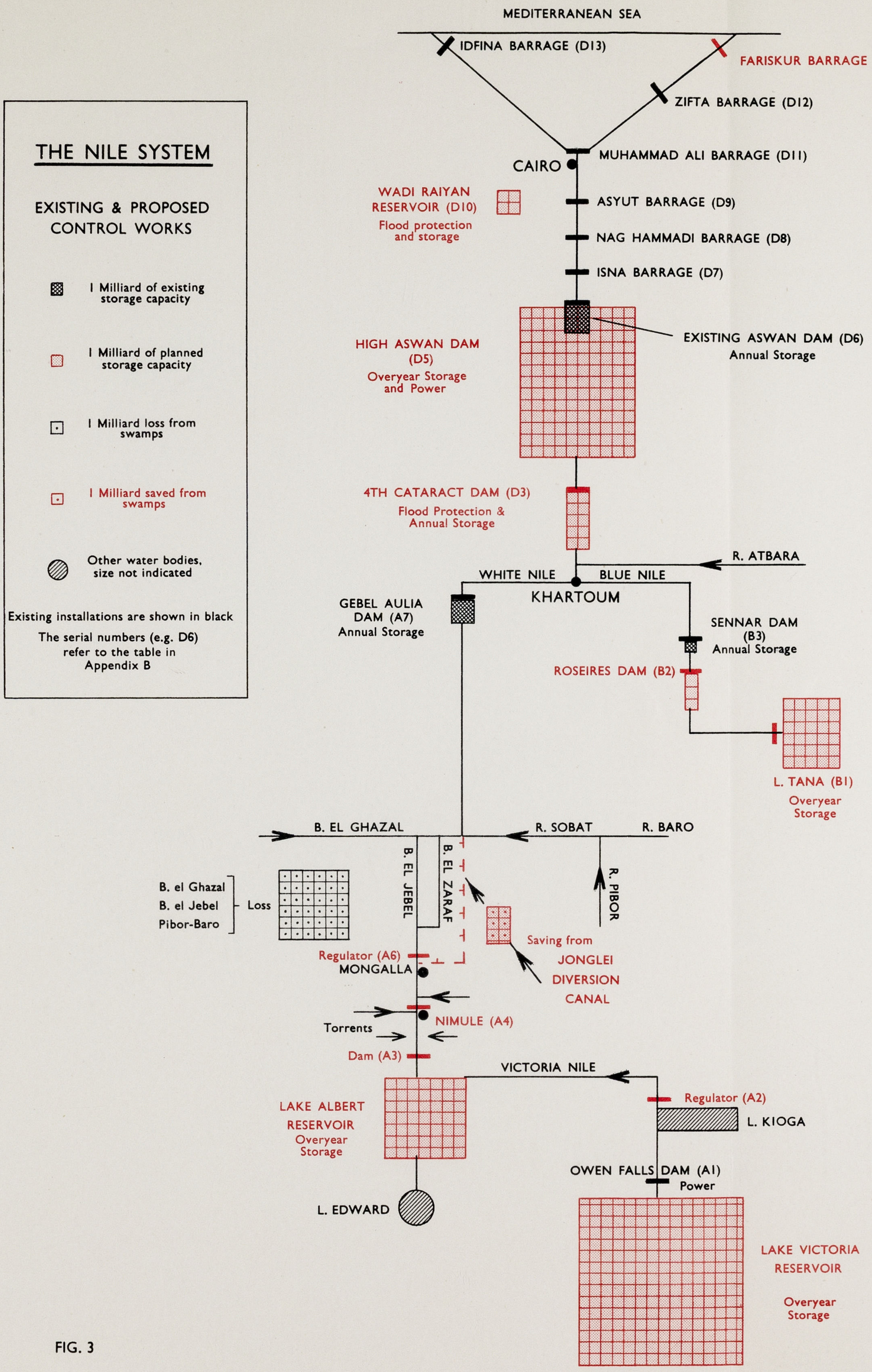

FIG. 3

Compiled and drawn by J.I.B. April '58

THE NILE

SCALE 1:7,500,000

International Frontiers	—·—·—
Existing Barrage	▬
Existing Dam	▬
Proposed Barrage Regulator or other control project.	- - -
Proposed Dam	⌒
Cataract	╪
Lake	○
Swamp	ᐃᐃ
Proposed Canal	▬
Existing Irrigation } Sudan only	▦
Proposed Irrigation } Sudan only	▨

The figures enclosed in circles are the normal discharges at the sites indicated. The top figure is for Sept., the middle for the year and the bottom for April. All are in millions of cubic metres per day. All are averages for 1912-1942 except where stated.

Barrages:
Raise water level for Irrigation.
No Storage

Aswan Dam:
Capacity approx. 5·3 milliard cu. m

High Dam Project
Planned capacity approx.
130 milliard cu. metres

Gebel Aulia Dam.
Reservoir gross capacity
approx. 3·5 milliard cu. metres
Egypt receives about 2·5 milliards,
rest lost by evaporation.

Sennar Dam.
Reservoir capacity
about 929 million cu. metres.
Mainly serves
Gezira scheme

50006-B269-5/58 (M.F.P.)

Compiled and drawn by J.I.B. April '58

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